Bioenerg. Res. (2009) 2:177–178
DOI 10.1007/s12155-009-9057-7

The Goals and Research of the BioEnergy Sciences Center (BESC): Developing Cost-effective and Sustainable Means of Producing Biofuels by Overcoming Biomass Recalcitrance

Brian H. Davison · Martin Keller · V. Suzy Fowler

Published online: 20 October 2009

Abstract The mission of BioEnergy Sciences Center is to understand and overcome the recalcitrance of biomass to conversion by modifying plant cell walls with improved biocatalysts. The papers in this volume are from the plant transformation and the biomass characterization areas, and showcase the multidisciplinary and multi-institutional nature of the center.

Keywords Biofuels · Bioenergy · Biofeedstocks

The challenge of converting cellulosic biomass to accessible sugars is the dominant obstacle to cost-effective production of biofuels in sustained quantities capable of impacting U.S. consumption of fossil transportation fuels. This was affirmed in a Biomass to Biofuels Workshop report, "Breaking the Barriers to Cellulosic Ethanol" (DOE/SC-0095, 2006). The potential beneficial economic impact of addressing the difficulty of accessing biomass sugars was explained by Lynd et al. [1]. The BioEnergy Science Center (BESC) research project addresses this challenge with an unprecedented interdisciplinary effort focused on overcoming the recalcitrance of biomass.

The 5-year mission of BESC is to make revolutionary advances in understanding and overcoming the recalcitrance of biomass to conversion into sugars, making it feasible to displace imported petroleum with ethanol and other fuels. BESC will combine plant cell walls engineered to reduce recalcitrance with new biocatalysts to improve deconstruction. These breakthroughs will be realized with a systems biology approach and new high-throughput analytical and computational technologies to achieve: (1) targeted modification of plant cell walls to reduce their recalcitrance (using *Populus* and switchgrass as high-impact bioenergy feedstocks), thereby, decreasing or eliminating the need for costly chemical pretreatment; and (2) consolidated bioprocessing, which involves the use of a single microorganism or microbial consortium to overcome biomass recalcitrance through single-step conversion of biomass to biofuels. We will greatly enhance our understanding of cell wall structure during synthesis and conversion. The data published will be made available through a Web portal to the bioenergy research community.

As can be seen in this volume of early papers, this is a multidisciplinary and multi-institutional project which began in the fall of 2007. In forming the BESC, leading researchers from institutions across the United States were recruited to establish a distributed team that brings an unprecedented breadth and depth of expertise to the challenge of biomass recalcitrance. More details on BESC can be found at www.bioenergycenter.org.

The papers in this volume primarily are from the plant transformation and the biomass characterization areas within the center. Since BESC is pursuing targeted modification of plant cell walls to reduce or eliminate pretreatment and to decrease recalcitrance, these papers show the variety of techniques that can be applied at both the plant (e.g., genetic transformation) and analytical levels. The collective goal is the understanding of cell wall biosynthesis at the molecular level and how cell wall structure and architecture influence recalcitrance.

For this purpose, there is insufficient knowledge about how cellulose and hemicelluloses are synthesized, distrib-

B. H. Davison (✉) · M. Keller · V. S. Fowler
Bioenergy Science Center,
P.O. Box 2008,
Oak Ridge, TN 37831-6342, USA
e-mail: davisonbh@ornl.gov

B. H. Davison · M. Keller · V. S. Fowler
Oak Ridge National Laboratory,
P.O. Box 2008, Oak Ridge, TN 37831-6342, USA

uted within cell walls, and attached to each other, to lignin, or to cell wall proteins. We are utilizing molecular, genetic, genomic, biochemical, chemical, and bioinformatics tools to understand cell wall biosynthesis in *Populus* and switchgrass. We chose switchgrass and *Populus* as realistic potential biofeedstocks and as representatives of herbaceous and woody perennial plants. While an ultimate goal is the development of optimal biofuel feedstocks for conversion, productivity, and sustainability, our immediate goal is to prove that controlled modification of plant cell walls will reduce their recalcitrance, decreasing or even eliminating the need for costly chemical pretreatment.

Within this effort, BESC has developed several new high-throughput (HTP) pipelines in order to enhance our ability to work together and to share samples and information. Two are relevant to the topics in this issue: a plant transformation pipeline and a characterization pipeline. Genetic tools for *Populus* and switchgrass are available, but the limitations on throughput required us to coordinate our ability to produce transformants for targeted key plant biosynthesis genes in a plant transformation pipeline. We use pathway knowledge, literature, expressed sequence tag (EST), and microarray data, phylogeny analysis as well as model plants tests to select several hundred genes per year for this transformation pipeline. We are also trying to improve the transformation tools for these species, in particular, for switchgrass. The first several hundred transformed plant lines are now moving through this pipeline and beginning to enter the greenhouses.

Samples from both native biomass and from these transformants enter into a new HTP biomass characterization pipeline for recalcitrance. BESC uses this screen to rapidly identify variants with better access to the sugars within biomass. In this pipeline, BESC is able to screen many small distinct samples of plant materials and take them through the key steps of a bioconversion process (compositional analysis, pretreatments, enzyme digestibility, and sugar release). This pipeline can screen more than 10,000 samples per week, which is over 100-fold more biomass samples per day than conventional methods. This large-scale screening of potential feedstocks will accelerate the discovery and isolation of plants most easily converted to biofuels, identify the beneficial properties, and provide new paths toward the development of improved biomass varieties. Other efforts provide more detailed studies of cell wall structure and chemistry as well as plant genetics and biosynthetic pathways. The goal of these studies is to understand the complexity of the plant cell wall and its relationship to recalcitrance in these realistic biofeedstocks.

The BESC team combines national lab, university, and industrial researchers working together. The home base of BESC is the Joint Institute for Biological Sciences on the Oak Ridge National Laboratory campus and built by the State of Tennessee and the University of Tennessee. It houses a suite of genomic, transcriptomic, proteomic, and metabolomic equipment for interdisciplinary systems biology research. Other BESC anchor facilities include the Complex Carbohydrate Research Center and the University of Georgia with extensive carbohydrate analytical and plant science expertise and the National Renewable Energy Laboratory with comprehensive biomass analysis expertise and bioprocessing capabilities. These anchors are complemented by specialized instrumentation and expertise provided by academic partners (Georgia Tech, the University of Tennessee, Dartmouth College, University of California-Riverside, Cornel University, Virginia Tech, Washington State University, University of Minnesota, West Virginia University, and North Carolina State University), Brookhaven National Laboratory, The Samuel Roberts Noble Foundation, and industrial partners (Mascoma, Verenium, ArborGen, and Ceres).

BESC is actively interacting with industry to ensure effective and rapid translation of scientific discoveries into commercial applications. This effort includes

- a pre-commercial-scale switchgrass-to-ethanol demonstration plant funded by the State of Tennessee with Genera and DuPont-Danisco Cellulosic Ethanol,
- a centralized intellectual property strategy providing "one stop shopping,"
- active outreach to industry via BESC research and development forums tailored to commercial partners, and a Board of Directors with members from the related industries
- industrial research partners integrated within the project and an open membership in the BESC affiliates program.

We already have over 14 invention disclosures posted on our website. The translation of characterization tools and plant materials into applications is critically important but must be based on improved fundamental understandings such as illustrated in the following articles.

References

1. Lynd LR, Laser MS, Bransby D, Dale BE, Davison B, Hamilton R (2008) How biotech can transform biofuels. Nat Biotechnol 26:169–172